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Pesticides in Water Supplies Using Surface Water Sources

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Study results indicate that current conventional water treatment technology is ineffective at substantial reduction of pesticide concentrations or elimination of pesticides from drinking water. Further, the study suggests that current pesticide monitoring requirements of the Safe Drinking Water Act are inadequate.

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Pesticides in Water Supplies Using Surface Water Sources

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Summary

A study was undertaken in the spring of 1986 by the Iowa Department of Natural Resources and the University Hygienic Lab to investigate pesticide contamination in water supplies using surface water sources. Samples of treated water were collected from 33 public water supplies which rely on a surface water as their sole source or as one of several permanent sources of water. All samples were collected after a rainfall event and thus represented pesticide levels in treated water affected by runoff. At 14 of these public water supplies, concurrent samples were also collected from the surface water source, prior to treatment. Sampling of water prior to and after treatment provided an indication of the effectiveness of pesticide removal during the treatment process. Each sample was analyzed for 37 pesticide compounds.

Of the 33 public water supplies tested, detectable levels of one or more pesticide compounds were found in 30 of the supplies. Individual pesticides and the number of supplies in which they were detected were: atrazine, 30; cyanazine (Bladex), 26; metolachlor (Dual), 21; alachlor (Lasso), 17; carbofuran (Furadan), 9; metribuzin (Sencor), 4; 2,4-D, 2; and, trifluralin (Treflan), butylate (Sutan) and dicamba (Banvel), 1 each. Overall in the treated water samples, ten individual pesticide compounds were detected out of the 37 analyzed.

All the pesticides detected in the treated water samples are identified as those most abundantly used on cropland. With the exception of 2,4-D, the pesticide compounds found at the public water supplies tested in this study are not required to be monitored through the federal requirements in the Safe Drinking Water Act (SDWA). In total, the SDWA only requires monitoring for six pesticide compounds in public water supplies using surface water sources. Of those required to be monitored only 2,4-D was detected in the treated water samples. The remaining pesticides, mandated to be monitored according to SDWA regulations, have limited or no current usage in Iowa.

Results from samples collected prior to and after treatment indicate that conventional water treatment systems are ineffective at substantially removing or eliminating pesticide compounds. Thirteen of 14 water supplies sampling both treated and untreated water had detectable levels of pesticide compounds in the untreated source water. All 13 of these supplies had detectable levels of one or more pesticide compound in their respective treated water samples. Although the water supplies tested provided results from a wide range of conventional treatment systems, evaluating the effectiveness of any one type of treatment system was beyond the scope of this study.

Pesticide concentrations in treated water at 21 of the 33 water supplies tested exceeded preliminary lifetime health advisory concentrations (MCL Goals). Although samples were collected after a rainfall-runoff event, the amounts of rainfall received and occurrence with respect to pesticide application varied among the water supplies tested. Due to these factors, as well as a number of others, neither the frequency or magnitude of pesticide contamination at these water supplies can be ascertained from this study. Concurrently, the frequency at which the lifetime health advisory concentrations in those water supplies is exceeded cannot be established.

The findings from this study support the following recommendations:

- commonly used pesticides should be monitored in public water supplies on a regular basis;

- there should be an increased public awareness of the presence of unregulated contaminants in drinking water;

- changes to the Safe Drinking Water Act should be supported to reflect current pesticide usage; and,

- the prevention of surface water contamination through more efficient chemical usage should be emphasized.

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Abstract

Between May and early July in 1986, samples of treated (finished) water were collected after rainfall from 33 public water supplies using surface water sources. These samples were analyzed for 37 pesticide compounds. Fourteen water supplies also collected samples from their surface water source prior to treatment to determine the effectiveness of treatment with regard to pesticide removal.

Detectable concentrations of one or more of ten pesticides were found in the treated water from 30 of the 33 water supplies tested. Individual pesticides and the number of supplies in which they were detected were: atrazine, 30; cyanazine (Bladex), 26; metolachlor (Dual), 21; alachlor (Lasso), 17; carbofuran (Furadan), 9; metribuzin (Sencor), 4; 2,4-D, 2; and, trifluralin (Treflan), butylate (Sutan) and dicamba (Banvel), 1 each.

Study results indicate that current conventional water treatment technology is ineffective at substantial reduction of pesticide concentrations or elimination of pesticides from drinking water. Further, the study suggests that current pesticide monitoring requirements of the Safe Drinking Water Act are inadequate.

GLOSSARY

"Community water system" means a public water supply system which has at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

"Detection limit" means the lowest concentration which gives an instrument response distinguishable from instrument/background "noise". This limit will not normally have a value assigned as it will vary from day to day depending on instrument response and sample matrices. The analyst will make an experienced judgement regarding the presence of a compound based on the instrument response, background, sample matrix, etc. for the sample in question.

"Maximum contaminant level" (MCL) means the maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water supply system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system. Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

"Public water supply system" means a system for the provision to the public of piped water for human consumption, if such system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year. Such terms include: 1) any collection, treatment, storage and distribution facilities under control of the supplier of water and used primarily in connection with such system, and 2) any collection (including wells) or pretreatment storage facilities not under such control which are used primarily in connection with such system. A public water supply system is either a "community water system" or a "noncommunity water system".

I. Introduction

A. Study Objectives

In 1986, the University Hygienic Laboratory (UHL) and the Iowa Department of Natural Resources (DNR) conducted a study on public drinking water supplies throughout the state that utilize surface water (e.g., rivers, lakes, reservoirs) as a water source. This study was conducted in the late spring and early summer of 1986. All samples were collected following rainfall-runoff. Therefore, the sampling protocol was designed to study a "worst case" situation.

The primary objective of this study was to determine if pesticides were present in these drinking water supplies. Previous monitoring (Johnson and Splinter, 1983) had shown that detectable concentrationss of pesticides were found at selected water supply intakes using surface water sources. With the heavy pesticide usage throughout Iowa (Wintersteen and Hartzler, 1986), this 1986 study attempted to determine how prevalent pesticides were in drinking water supplies using surface water sources and to assess what types of surface water sources were more susceptible to pesticide contamination.

A secondary objective of this study was to examine treatment effectiveness for removal of pesticides. At selected water supplies, a sample was collected of the untreated water (at the intake) followed with a sample of treated water after allowing adequate time for treatment processing. Comparison of the concentrations of pesticides found in the treated sample with the untreated sample should indicate the effectiveness of treatment upon pesticide removal.

The Safe Drinking Water Act (SDWA) does not require water supplies to monitor for most of the pesticides currently being used. Sampling under an assumed "worst case" scenario was performed to provide information to assess the potential of contamination in drinking water supplies from a wide spectrum of the pesticide compounds currently being used.

B. Water Supplies Participating in the Study

While the majority of Iowa's drinking water is obtained from ground water sources, there are 52 community public water supplies which utilize surface water as their sole source, as a partial source to blend with other permanent sources, or, as an emergency source. Thirty-eight of these 52 community public water supplies were asked by DNR to participate in the study. Samples were received from the 34 water supplies listed in Table 1. A listing of the individual facilities participating in the study, the population served by the water facility, the surface source used and the facility's dependency upon the surface source are identified and included in Table 1.

Selection of those supplies participating in the study was based primarily on obtaining a statewide representation. On major rivers, except the Mississippi River, only one facility was generally selected. A map showing the statewide distribution of facilities participating in this study is provided in Figure 1. As evident in Figure 1, the

TABLE 1

Water Supplies Sampled

Water Supply	Population Served By Supply	Surface Source Sampled	Number and Type of Available Water Sources	
			Surface	Ground Water
Afton	985	Afton West Lake	1-P	
*Albia	4,184	Reservoir	1-P,1-E	1-E
*Bedford	1,692	Scane Lake	2-P	
**Bloomfield	3,061	Lake Fisher	1-P,1-I	
Burlington	31,451	Mississippi River	1-P	
Central Water System	1,610	West Lake Okoboji	1-P	
*Clarinda	9,467	Nodaway River	1-P,1-E	
Clear Lake	7,458	Clear Lake	1-P	1-P
Corydon	1,818	Corydon Lake	1-P,1-I	
*Council Bluffs	56,699	Missouri River	1-P	1-E
Creston	8,429	Twelve Mile Reservoir	2-P	
*Davenport	134,975	Mississippi River	1-P	
*Des Moines	234,027	Des Moines River	2-P	1-P
Fairfield	10,964	Walton Reservoir	1-P	2-E
*Fort Madison	13,520	Mississippi River	1-P	2-P
Greenfield	2,243	Lake Greenfield	2-P	
*Humeston	671	Reservoir	1-P	
Keokuk	13,536	Mississippi River	1-P	
Lake Park	1,123	Silver Lake	1-P	
*Lakeview Heights Homeowners Assn.	140	Reservoir	1-P	
Lamoni	2,705	Home Pond	2-P	
Lenox	1,338	Maharry's Lake	3-P	
Montezuma	1,683	Diamond Lake	1-P	
Mount Ayr	1,938	Lake Ayr	1-P	
Mount Pleasant	7,372	Skunk River	1-P	2-P
*Orient	416	Lake Orient	1-P	
Osceola	4,000	West Lake	1-P	
*Ottumwa	31,891	Des Moines River	1-P	
*Panora	1,211	Middle Raccoon River	1-P	
*Rathbun RWA	15,390	Lake Rathbun	1-P	
Spirit Lake	4,522	Spirit Lake	1-P	
Sun Valley RWA	720	Sun Valley Lake	1-P	
*University of Iowa	20,000	Iowa River	1-P,1-E	
Winterset	4,021	Cedar Lake	1-P	1-P

*Indicates systems where both treated and untreated water samples were collected. All other water supplies sampled only treated (finished) water except **.

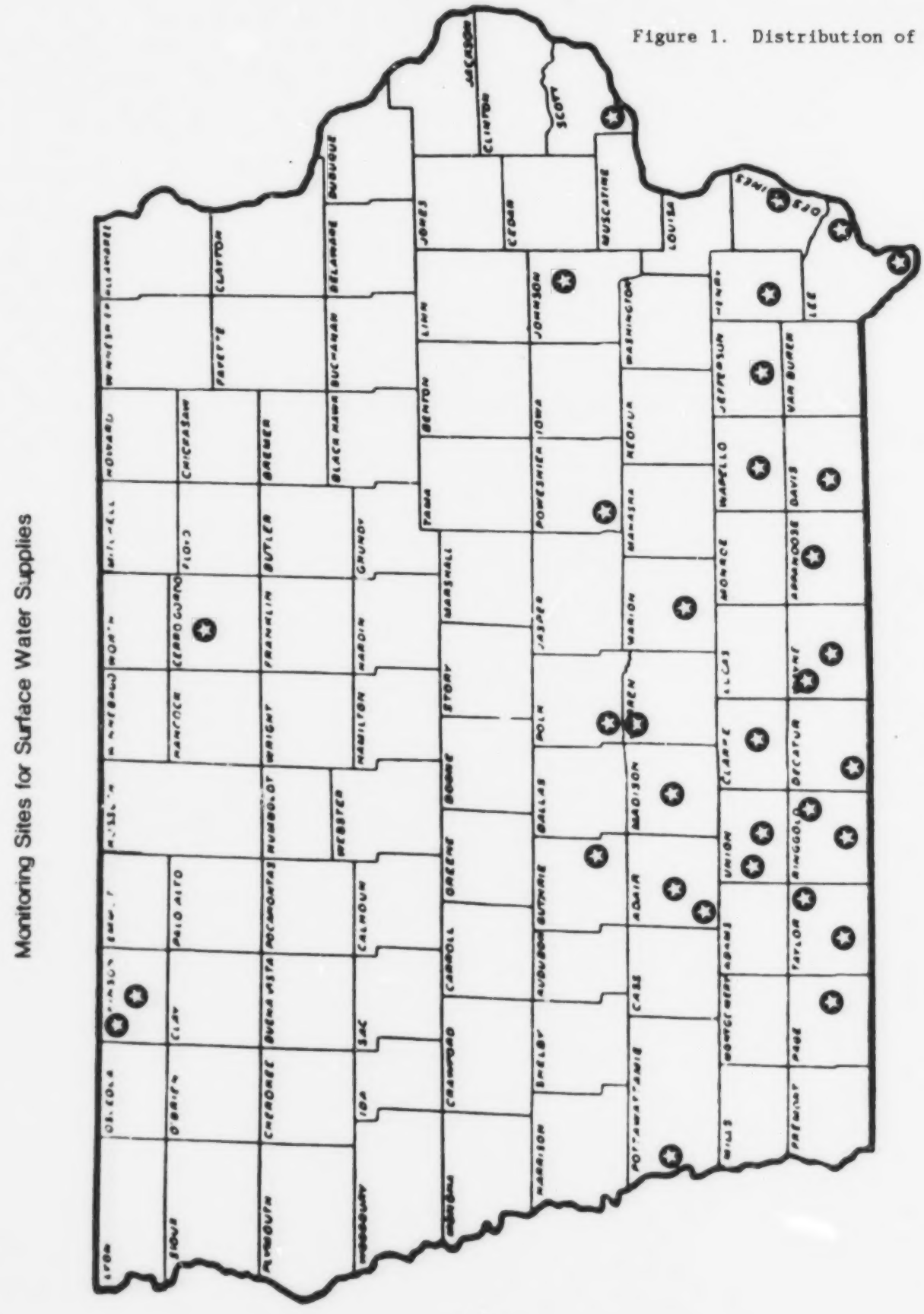
**Sampled untreated (raw) water only.

Source Type Code

P = permanent
E = emergency
I = interim[a]

[a]Permanent but used only when needed.

Figure 1. Distribution of Facilities



majority of public water supplies using surface water sources are located in southern Iowa. Ground water of good quality is generally not available in southern Iowa and the general topography is suitable for constructing surface water impoundments.

All supplies participating in the study were requested to collect a sample of their treated water that would have been affected by rainfall-runoff. Fourteen of these supplies also provided a sample of the intake water prior to treatment so that pesticide removal could be determined by comparing the sample results. Selection of the supplies providing both untreated and treated samples was based on obtaining a representation of differing treatment systems.

C. Pesticides Selected For Analysis

All samples submitted as part of this study were analyzed by the University Hygienic Laboratory (UHL) for 37 pesticide compounds. These compounds, pesticides or their breakdown products, are listed in Table 2 along with each compound's detection limit. Selection of pesticide compounds for analysis was based on the following considerations:

- includes all pesticides required to be monitored by surface water supplies pursuant to the federal Safe Drinking Water Act (SDWA) with the exception of methoxychlor;
- based on usage data, this list of pesticides has the greatest potential of being found in Iowa surface waters; and,
- allows for a comparison of the results of this study with previous surface and ground water studies.

D. Pesticide Monitoring Requirements for Water Supplies

The Department of Natural Resources (DNR) administers Iowa's public water supply program. Iowa's public water supply program is consistent with the requirements in the federal Safe Drinking Water Act (SDWA). Drinking water standards, including maximum contaminant levels (MCLs), and monitoring requirements imposed in Iowa's administrative rules on public water supplies are based on SDWA requirements. DNR's regulatory authority over private water supplies in the state only applies to minimum location and construction standards. Thus, there are no DNR monitoring requirements of private water supplies in Iowa.

Only six pesticides are required to be monitored under the federal SDWA requirements. The MCLs for these six pesticides which are applicable to all community public water supplies are presented below in Table 3.

TABLE 2

Pesticide Compounds Analyzed in the Samples

Compound*	Detection Limit (µg/l)
Aldrin (HHDN)	0.04
alpha-BHC (α Benzene Hexachloride)	0.04
beta-BHC (β Benzene Hexachloride)	0.04
delta-BHC (δ Benzene Hexachloride)	0.04
gamma-BHC (Lindane)	0.04
Chlordane	0.2
DDD (TDE)	0.04
DDE	0.04
DDT (Dichlorodiphenyltrichloroethane)	0.04
Dieldrin (HEOD)	0.04
Endosulfan I (Thiodan I)	0.04
Endosulfan II (Thiodan II)	0.04
Endosulfan Sulfate	0.04
Endrin (Endrex)	0.04
Endrin aldehyde	0.04
Heptachlor	0.04
Heptachlor Epoxide	0.04
Polychlorocamphene (Toxaphene)	0.5
Fonofos (Dyfonate)	0.1
Terbufos (Counter)	0.1
Chlorpyrifos (Lorsban)	0.1
Phorate (Thimet)	0.1
Ethoprop (MoCap)	0.1
AAtrex (Atrazine)	0.1
Cyanazine (Bladex)	0.1
Alachlor (Lasso)	0.1
Trifluralin (Treflan)	0.1
Metribuzin (Sencor)	0.1
Metolachlor (Dual)	0.1
Chloramben (Amiben)	0.1
Dicamba (Banvel)	0.1
2,4-D	0.1
2,4,5-TP (Silvex)	0.1
Butylate (Sutan)	0.1
Carbofuran (Furadan)	0.1
Sulprofos (Bolstar)	0.1
Terbufos sulfone	0.1

*Common trade name given in parenthesis

All community public water supplies utilizing surface water sources are required to monitor for those pesticides listed in Table 3, at a minimum, once every three years. According to state regulations, treated water samples are to be collected during the period of the year designated by DNR as the period when contamination by pesticides is most likely to occur. DNR has designated the months of April, May and June as the sampling period for required pesticide monitoring. If the pesticide level in treated water exceeds the MCL, the supplier of water would, at the least, be required to perform additional, more frequent monitoring.

TABLE 3

Maximum Contaminant Levels for Pesticides

Compound	MCL (mg/l)
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4-D	0.1
2,4,5-TP (Silvex)	0.01

The DNR also has the authority to require monitoring for other pesticides in addition to those contained in Table 3. 563--41.4(15) of the Iowa Administrative Code contains the following provision:

> "41.4(15) If the department determines that other contaminants are present in a public water supply, and the contaminants are known to pose or scientific evidence strongly suggests that they pose a threat to human health, the supplier of water is to monitor for such contaminants."....

At the time of this study, none of the water supplies that were sampled were required to monitor for any other pesticides than the six required by the SDWA regulations, and none were required to sample more frequently than once every three years.

E. Previous Pesticide Monitoring

The monitoring of pesticides in surface and ground waters has become of recent importance. An increased occurrence in the detection of pesticides and concern for public health from the use of water contaminated with one or more pesticides have led to an increased emphasis for pesticide monitoring. Several previous pesticide

monitoring efforts in Iowa have indicated that drinking water supplies are being contaminated by commonly used pesticides. A brief review of previous monitoring efforts in Iowa is contained below. The results of these studies provide insight into the extent of pesticide contamination in the state's ground and surface waters, and, the effectiveness of water supply treatment in removing pesticides.

UHL Monitoring

Between 1968 and 1982, the UHL monitored pesticides in 12 different surface waters near public water supply intakes (Johnson and Splinter, 1983). Monitoring was initiated because of concerns with chlorinated hydrocarbon insecticide compounds such as DDT, dieldrin and DDE. Monthly samples were collected by the water supply operators. Thus, samples should be representative of varying flow regimes experienced throughout the year.

A thorough analysis of the data has not yet been completed, but Figure 2 provides an overview of the results (Kelley et al., 1986). Data on the now-banned pesticides dieldrin and DDT and its by-product DDE go back to 1968. Over time, residues of DDT and DDE were detected less frequently, and by 1981 samples seldom contained detectable residues. Dieldrin, on the other hand, continued to appear in about 35-40% of the samples. Dieldrin has a very strong affinity to attach to soil particles (clay, organic matter, colloids) and its appearance was typically related to some turbidity, and the concentrations were very low (less than 10 parts per trillion).

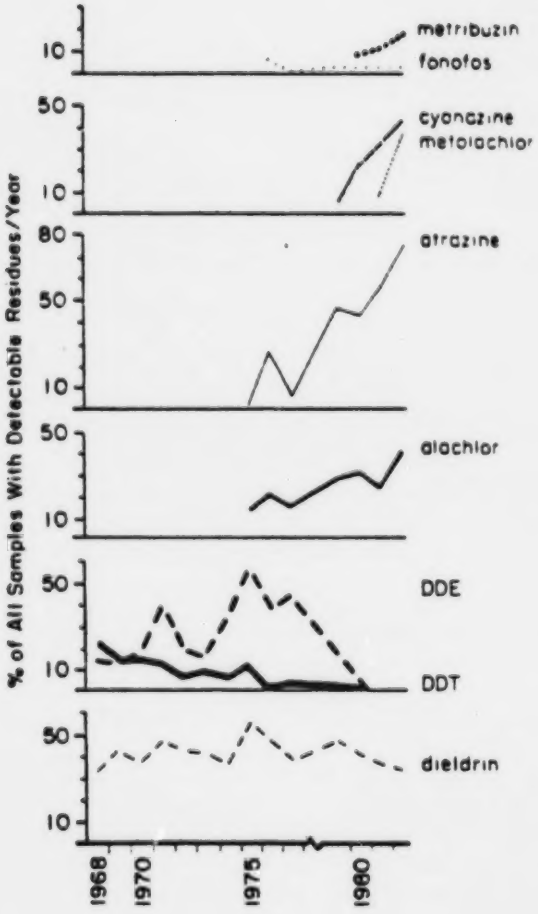
In 1975, UHL modified procedures and began analyzing for the more "modern" pesticides which came into use. Although some changes in methods took place after 1975, detection limits remained nearly the same, and the trends shown are not the result of more sensitive testing methods. For all the modern herbicides, the trend is the same (Figure 2). All increase in their occurence with time; e.g., atrazine to nearly 80% by 1982, alachlor (Lasso) and cyanazine (Bladex) to 40-50%. By 1980, at some sampling stations, a number of the herbicides were present even in winter base-flow samples.

Iowa State University Study

In 1974, a study was undertaken to examine the presence of the pesticides atrazine, DDE and dieldrin in surface, subsurface (shallow alluvial) and finished drinking waters in the State of Iowa (Richard et al., 1974). The study found that every major watershed revealed some degree of pesticide contamination and that seasonal variations existed. Atrazine, DDE and dieldrin were found in most of the water samples tested. Pesticide contamination generally was found to exist in all waters which originated from the shallow wells in the alluvial plains of contaminated rivers and in all finished waters that originated from either surface waters or shallow wells. In examining treatment removal of pesticides at several finished (treated) water supplies, the study demonstrated that the water treatment processes currently used by the supplies monitored were ineffective at reducing or eliminating these pesticides from the water; this included treatment with activated carbon.

Figure 2. UHL Monitoring Results

Percent of All Samples Per Year Which Had Detectable Pesticide Residues, From Monthly Sampling of 12 Surface Water Sites in Iowa vs. Time.



Monsanto Study

Between May 1985 and March 1986, untreated and treated samples were collected approximately weekly from the Clarinda, Davenport and University of Iowa community public water supply systems (Monsanto, 1986a). Samples were analyzed by the Monsanto Company for the following pesticides: atrazine, alachlor (Lasso), cyanazine (Bladex), linuron, metolachlor (Dual), metribuzin (Sencor), simazine and trifluralin (Treflan). A summary of the results from this study is presented in Table 4. By comparing the results of untreated and treated samples, Monsanto concluded that conventional water treatment was not effective at removing alachlor (Monsanto, 1986b). Utilizing the same approach, the data generated in the study also showed that conventional water treatment was ineffective at removing atrazine, cyanazine and metolachlor.

TABLE 4

Monsanto's 1985-1986 Study Results
Frequency of Positive Pesticide Detections and Maximum Observed Concentrations (in µg/l or ppb) in Selected Water Supplies*

	University of Iowa		Davenport		Clarinda	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
atrazine	38/45 (2.76)	41/48 (2.95)	36/44 (1.20)	16/46 (0.56)	36/41 (3.86)	37/46 (2.15)
alachlor (Lasso)	5/41 (1.59)	6/45 (1.76)	2/40 (0.68)	1/42 (0.32)	0/34 (<.02)	0/39 (<.02)
cyanazine (Bladex)	23/45 (1.51)	21/48 (1.54)	11/44 (0.49)	7/46 (0.25)	32/41 (2.6)	25/46 (1.30)
linuron	1/45 (0.20)	1/48 (0.23)	1/44 (1.03)	0/46 (<.20)	0/41 (<.20)	0/46 (<.20)
metolachlor (Dual)	17/45 (1.80)	11/48 (0.87)	1/44 (0.55)	1/46 (0.23)	11/41 (0.68)	12/46 (0.82)
metribuzin (Sencor)	1/45 (0.28)	0/48 (<.20)	0/44 (<.20)	0/46 (<.20)	0/41 (<.20)	0/46 (<.20)
simazine	0/45 (<.20)	0/48 (<.20)	0/44 (<.20)	0/46 (<.20)	1/41 (0.27)	0/46 (<.20)
trifluralin (Treflan)	0/45 (<.20)	0/48 (<.20)	0/44 (<.20)	0/46 (<.20)	0/41 (<.20)	0/46 (<.20)

*Ratio provided in Table refers to the number of samples having concentrations above the detection limit over the total number of samples analyzed. The number in parenthesis is the maximum observed concentration in µg/l or ppb.

USGS Special Study

A cooperative study between UHL and the United States Geological Survey (USGS), conducted in 1984 and 1985, examined surface water quality in the Cedar River basin (USGS, 1986). In the study, emphasis was placed on investigating the occurrence of and transport of herbicides. Samples were collected from at least six locations within the basin. At each sampling location, both centrifuged and uncentrifuged samples were analyzed for pesticides. This technique provided information to determine the fraction of pesticides attached to settleable material in the sample (e.g., suspended sediments, organics) as compared to the fraction of pesticides found in the soluble phase. Data from this study demonstrated that removal of settleable material generally had little or no effect on the herbicide concentration in a sample. Thus, the majority of today's commonly used herbicides are being transported in the water phase, not attached to sediment particles as had been previously thought to be the principal transport mechanism.

Ground Water Studies

More recently, monitoring for pesticides in Iowa has focused on ground water. A number of research and monitoring studies have shown that water supplies across the state are being contaminated by commonly used pesticides (Hallberg and Hoyer, 1982; Hallberg et al., 1983; Hallberg et al., 1984; Kelley, 1985; Kelley and Wnuk, 1986; Kelley et al., 1986). These studies began in 1981 and have found that public water supplies using relatively shallow ground water, and hence particularly supplies on alluvial aquifer systems, are extremely susceptible to pesticide contamination.

In terms of the individual compounds detected, the concentrations observed and the percent of samples in which pesticides have been detected, there has been a close correlation between the findings from the monitoring of Iowa's ground water and surface water. This is not surprising in that the state's water systems actually represent a highly interrelated hydrologic unit. The base flow for nearly all of Iowa's interior streams is ground water discharge.

F. Statewide Pesticide Usage

Pesticides (herbicides and insecticides) have become an integral part of today's farming operations. Iowa's farmers treat over 97% of the state's corn and soybean acreage each year with pesticides (Wintersteen and Hartzler, 1986). Approximately 75 million pounds of pesticide active ingredient were applied in 1985 alone (Gianessi, 1986). Table 5 identifies the most abundantly used pesticides, by weight of active ingredient, applied to Iowa's agricultural lands.

With the exception of 2,4-D, the remaining five pesticides required to be monitored according to SDWA and state regulations, are not identified as high use pesticides in Table 5. Table 6 contains the present status of use for these six pesticides. Where identified in Table 6, a "restricted use" pesticide is a designation imposed by the Environmental Protection Agency (EPA). A "restricted use" pesticide is restricted to only those specific uses as identified in Table 6, and, must be applied by a certified operator.

TABLE 5

Major Pesticides Applied to Iowa Cropland
Listed in alphabetical order.
(Wintersteen and Hartzler, 1986)

HERBICIDES

Common Name	Typical Trade Name	Common Name	Typical Trade Name
alachlor	Lasso	dicamba	Banvel
atrazine	AAtrex	EPTC+safening add.	Eradicane
bentazon	Basagran	metolachlor	Dual
butylate	Sutan+	metribuzin	Lexone/Sencor
chloramben	Amiben	trifluralin	Treflan
cyanazine	Bladex	2,4-D	used in many multiple mixes

INSECTICIDES

Common Name	Typical Trade Name	Common Name	Typical Trade Name
carbofuran	Furadan	permethrin	Ambush
chlorpyrifos	Lorsban	phorate	Thimet
ethoprop	MoCap	terbufos	Counter
fonofos	Dyfonate		

G. Surface Supply Treatment Methods

Public water supplies in Iowa that use surface streams as a source of water face many difficulties in treatment that supplies using ground water for their source do not have to resolve. Surface water treatment plants must remove objectionable color, tastes and odors and potentially pathogenic microbes. In addition, Iowa's streams can carry heavy loads of sediment and a multitude of chemical pollutants.

Surface water treatment plants are required to meet specific drinking water standards with regard to turbidity, bacteria and certain inorganic and organic chemicals. To meet these standards, and to provide water of acceptable quality to consumers, water treatment plants routinely filter water through sand or some other granular substance. Typically, the treatment these plants use is chemical addition to cause the suspended solids to coagulate and form a settleable material. The combination of chemical addition and filtration have proven to be effective in removing heavy sediment loads and attached pollutants.

TABLE 6

Usage of SDWA Required Monitoring Pesticides

Compound	Status	Usage
Endrin	restricted use	use is restricted to a bird perch poison
Lindane	restricted use for commercial application	use is restricted as a soybean insecticide, lice control for cattle and hogs, and borer insecticide
	general use for home and garden	insecticide
Methoxychlor	general use	basic seed treatment; also used as a residual insecticide
Toxaphene	restricted use	use is restricted to scabies control for cattle and sheep applied through dip vat machines
Silvex	cancelled	product was removed from the market in 1983
2,4-D	general use	high use herbicide

Source: C. Eckerman, Department of Agriculture and Land Stewardship

The filtration systems of the 34 plants monitored in this study ranged from rapid sand filters to granular activated carbon (Table 7). Chemical addition ranged from alum and lime to more sophisticated and numerous compound additions. None of the treatment systems in this study were specifically designed to remove pesticides (synthetic organic contaminants) in solution. These treatment systems do, however, represent the most sophisticated treatment systems in use Iowa.

TABLE 7

Treatment Methods Used by Water Supplies

	Chemical Addition*	Filtration
Afton	A, L, C	sand
Albia	A, L, SA, P, K, CS	sand
Bedford	AS, L	sand
Bloomfield	A, L	N.S
Burlington	C, P, L, A, CO_2	sand
Central Water System	K, PO, A, PP	sand
Clarinda	AS, C, L	N.S
Clear Lake	L, A, K	sand
Corydon	L, A, PO	sand
Council Bluffs	CS, PO, L, SA, IS, PP	sand (anthracite, sand and gravel)
Creston	A, L	sand
Davenport	PO, C, L, NH_3, filter aid, K, AS	granular activated carbon
Des Moines	A, C, K, SAL	sand
Fairfield	A, L, FC, K, C, P	carbon media
Fort Madison	PO, C, L, CO_2	sand
Greenfield	A, PO, C, SA	N.S
Humeston	A, L	sand
Keokuk	A, L, C, CO_2, NH_3, PP	sand
Lake Park	A, L	sand
Lakeview Heights Homeowners Assoc.	A, L	Anthrifilt
Lamoni	A, L	N.S
Lenox	A, L, C	sand
Montezuma	A, L, C	anthracite and sand
Mount Ayr	L, A, PO, C	sand
Mount Pleasant	L, SA, C, A	sand
Orient	A, L, C, K	sand
Osceola	AS, L	N.S
Ottumwa	IS, A, NH_3, P	sand
Panora	AS, L	sand
Rathbun RWA	IS, L, CO_2, PP	sand/carbon filter
Spirit Lake	L, A, K, PO	N.S
Sun Valley RWA	A, SA or CA	sand
University of Iowa	A, SA, L, CO_2, PP	N.S
Winterset	A, L, K, C	sand

*Codes

A = Alum
AS = Aluminum Sulfate
L = Lime
SA = Soda Ash
P = Phosphate
K = Potassium Permanganate
CS = Copper Sulfate
CO_2 = Carbon Dioxide
C = Carbon
PP = Polyphosphate
PO = Polymer
IS = Iron (III) Sulfate
SAL = Sodium Aluminate
FC = Ferric Chloride
CA = Caustic Soda
NH_3 = Ammonia

Type of Filtration
N.S = Not Specified in File

II. Methodology

A. Sampling Methods

Water supply superintendents were contacted by DNR staff in the latter part of April 1986 requesting their participation in this study by collecting samples following any rainfall-runoff event between May and July 1, 1986. With the unpredictability of rainfall, the sample collectors were recommended to sample as early as possible after May 1. Study instructions explaining when to collect the samples were attached to the study notification letters. Sample bottles, a copy of the instructions, and sampling instructions explaining how to collect and label samples and return samples to the UHL were sent out by UHL the first week of May.

Twenty-four surface water supply systems were asked to collect a sample of treated water at their treatment plant that was affected by runoff. These water supplies were asked to determine when their water source was at its poorest quality as affected by runoff (based on best judgement), then allow the water to pass through the treatment system, and collect a sample. In addition, 14 surface water supplies were asked to collect a sample of both their poorest quality source water as affected by runoff and a sample of this water after it had passed through the treatment process. To estimate when the source water had undergone treatment, water supplies were asked to utilize their plant's approximate hydraulic retention time, the estimated time for treatment.

Samples were to be packed in ice or with ice packs and sent to the UHL in Iowa City no later than 24 hours after collection via Purolator. Sample collectors were also asked to complete a sampling information form with each sample submitted. Information requested on this form included: sampling location, sampling date, date of and amount of rainfall received, and estimated hydraulic retention time through the plant.

B. Analytical Methods

Each sample consisted of two one-quart glass jars, specially cleaned and solvent-rinsed with Teflon-lined lids. One jar was used for extraction, concentration, derivatization and analysis of the acid herbicides according to UHL method PR-2 (essentially Standard Methods 509B using two dissimilar capillary columns for quantitation and simultaneous confirmation on a gas chromatograph with electron capture detectors) (American Public Health Association, 1985). The other jar was extracted with 45% methylene chloride in hexane, and after concentration, the extract was analyzed according to UHL method PR-9. This method uses two gas chromatographs, each equipped with two dissimilar capillary columns for quantitation and simultaneous confirmation, for detection of chlorinated hydrocarbon insecticides with electron capture detectors on one instrument and detection of carbonates, organophosphates, and triazine herbicides in one or more runs on the other instrument with NP-specific detectors. The compounds to be determined and the detection limits obtained are listed in Table 2.

III. Results and Discussion

A. General Data Assessment

Of 38 water supplies requested to participate in this study, 35 submitted samples. Because of a laboratory accident, one sample was lost. In total, samples of treated (finished) water from 33 supplies were analyzed for the pesticide compounds listed in Table 2. Fourteen of these supplies also submitted corresponding untreated water samples from their surface water source. One supply provided a sample of untreated water only. The location and type(s) of sample(s) analyzed as part of this study are identified in Table 1. The total population served by the water supplies listed in Table 1 is 635,260, representing approximately 22% of the state's estimated current population.

From all the samples analyzed, ten different pesticide compounds were found at levels above the detection limit. The facilities, type of sample collected, date(s) collected, and detectable pesticide concentrations are contained in Appendix I. All samples were analyzed for the pesticide compounds listed in Table 2 with the following exception. Because of a laboratory accident, four of the 48 samples were not analyzed for the acid herbicides which includes 2,4-D, dicamba, Silvex and chloramben.

Of the 33 samples of treated (finished) water submitted from different surface water supplies, all but three contained a detectable concentration of at least one pesticide compound. Atrazine was present in every one of the water supplies with a detectable level of one or more pesticide compound. Table 8 summarizes the frequency of positive pesticide detections (those pesticides in concentrations at or greater than the detection limit) to the total number of samples analyzed for treated and untreated water samples.

The frequency of the detection of pesticides in treated water supply samples, from increasing to decreasing order, is: atrazine (91%); cyanazine (79%); metolachlor (64%); alachlor (52%); carbofuran (27%); metribuzin (12%); 2,4-D (7%); and, dicamba, trifluralin and butylate (3%). In the untreated water samples, the following frequency of pesticide detection, from increasing to decreasing order, is: atrazine (93%); cyanazine and metolachlor (73%); alachlor (67%); carbofuran (33%); 2,4-D (14%); and, metribuzin and dicamba (7%). Butylate and trifluralin were not detected in any of the untreated samples analyzed. Of the pesticides detected, either in treated or untreated water samples, all can be found in Table 5 which lists the most abundantly applied pesticides, by weight of active ingredients. From the water supplies sampled, 27 of 33 (82%) had multiple pesticide residues (more than one pesticide detected) in the treated water; and, 12 of 15 (80%) had multiple residues in the untreated source water. The number of samples with multiple residues, the number of residues and population served are listed in Table 9.

TABLE 8

Occurrence of Positive Pesticide Detections

	atrazine	cyanazine (Bladex)	metolachlor (Dual)	alachlor (Lasso)	metribuzin (Sencor)	trifluralin (Treflan)	butylate (Sutan)	carbofuran (Furadan)	2,4-D	dicamba (Banvel)
treated water	30/33 (91%)	26/33 (79%)	21/33 (64%)	17/33 (52%)	4/33 (12%)	1/33 (3%)	1/33 (3%)	9/33 (27%)	2/30 (7%)	1/30 (3%)
untreated water	14/15 (93%)	11/15 (73%)	11/15 (73%)	10/15 (67%)	1/15 (7%)	0/15 (0%)	0/15 (0%)	5/15 (33%)	2/14 (14%)	1/14 (7%)
total	44/48 (92%)	37/48 (77%)	32/48 (67%)	27/48 (56%)	5/48 (10%)	1/48 (2%)	1/48 (2%)	14/48 (29%)	4/44 (9%)	2/44 (5%)

KEY: # of positive detections / # of samples analyzed (percent)

TABLE 9

Occurrence of Detectable Pesticide Compounds in Treated Water Samples

Number of Individual Pesticides Detected in Treated Water Samples	Number of Supplies With the Number of Pesticides Listed in Column 1	Population Served by These Supplies	Percent of Water Supplies in the Study Containing an Equal or Greater Number of Pesticide Residues Listed in Column 1
1	3	136,725	91%
2	3	2,828	82%
3	5	33,222	73%
4	12	115,485	58%
5	3	239,386	21%
6	3	15,874	9%
7	1	20,000	3%

Thus, from Table 9, 82% of the supplies tested had two or more pesticides detected in the treated water samples, 73% had three or more pesticides detected, 58% had four or more pesticides detected, 21% had five or more pesticides detected, 9% had six or more pesticides detected, and 3% had seven pesticides detected.

The range and mean value of detected pesticide concentrations is provided in Table 10.

TABLE 10

Range of Detected Pesticide Concentrations and Mean Value
µg/l

Pesticide	Treated Water Range	Treated Water Mean	Untreated Water Range	Untreated Water Mean
atrazine	0.13 - 24.0	3.8	0.18 - 26.0	4.9
cyanazine	0.13 - 17.0	2.7	0.12 - 20.0	3.8
metolachlor	0.1 - 21.0	2.9	0.1 - 10.0	2.8
alachlor	0.16 - 8.8	1.1	0.13 - 9.3	1.7
metribuzin	0.14 - 0.45	0.29	0.89	0.89
trifluralin	0.13	0.13		
butylate	0.27	0.27		
carbofuran	0.18 - 14.0	3.76	0.72 - 17.0	7.1
2,4-D	0.15 - 0.30	0.23	0.15 - 0.17	0.16
dicamba	1.4	1.4	1.2	1.2

B. Treatment Effectiveness

Fourteen of the water supplies participating in this study collected samples of both untreated water and treated water. The treated water sample was to be collected after allowing for adequate treatment time through the plant after collection of the untreated sample. The purpose of collecting the two samples from various water treatment systems was to determine how effective the treatment process was at removing pesticides. The analytical results comparing pesticide concentrations in treated and untreated samples are presented in Table 11. Caution, however, must be utilized in reviewing these results. Bedford, Des Moines and Fort Madison have more than one permanent source of water. Where multiple permanent sources were available, this study failed to obtain necessary information on the blending of these sources. Thus, if blending of different water supply sources occurred, the results in the treated (finished) water sample may be an artifact of dilution with other sources rather than treatment effectiveness. Also, in reviewing sampling information furnished by the water supplies (Appendix II), the collection of samples according to directions is suspect in some cases. Treated and untreated samples from Albia, Bedford and Orient were reportedly collected at the same time; whereas the treated water sample from Clarinda was reportedly collected prior to collecting the untreated samples. For some systems, this may have been the only good way to sample. Because of the short hydraulic retention times of these facilities, it will have to be assumed that pesticide concentrations in the source water did not change significantly.

Data to support this assumption is available from one of the sampling locations. By coincidence on May 19, 1986, one day after the University of Iowa (U of I) treated water sample was collected, a water sample was collected from the water tap at DNR's Geological Survey

Bureau's office, which happens to be served by the U of I system, and analyzed for many of the pesticides included in this study. The results from the sampling on May 19, 1986 are included in Table 11 and show some rather comparable results.

In reviewing the results in Table 11 for the eleven water supplies with only one permanent source, there does not appear to be any significant reduction of pesticide levels in the water source after treatment. Overall, in 51 observed changes in detectable pesticide concentrations between respective untreated and treated samples, concentrations decreased slightly in 38 observations, with a median decrease of .25 µg/l, and, increased in 13 observations, with a median increase of .20 µg/l. The anomoly of an increase in pesticide concentration after with treated water has been previously observed (Richard et al., 1974).

Student's t-tests were performed for atrazine, alachlor, metolachlor, cyanazine and carbofuran to evaluate whether the average change from untreated to treated (finished) water was significantly different from zero; zero being expected if there was no pesticide reduction through treatment. The t-test for all five pesticides showed no statistical difference from zero. This suggests no removal of these materials in the treatment facilities.

For the 13 of these 14 water supplies with detectable concentrations of pesticides in the untreated water, all had detectable concentrations of pesticides in the treated water. Water supply treatment did not appear to substantially reduce or eliminate pesticides from the source water, even with activated carbon filtration as in the case at Davenport. Insufficient data is available from this study to evaluate the removal effectiveness specific treatment methods have on individual pesticide compounds. To develop this database, monitoring of individual treatment techniques over extended periods of time would be necessary.

It was previously thought that pesticides were attached to sediment particles and removal of turbidity in the source water would consequently remove the pesticides. This may have been true for older chlorinated hydrocarbons, but data from this study does not support that argument for many of the currently used pesticides. Recent studies (USGS, 1986) have shown that the majority of modern pesticides are in the soluble fraction, not attached to particulate matter that could be filtered or precipitated out. While most water supply treatment facilities are readily capable of removing turbidity, taste and odor, and bacteria, none of the systems sampled in this survey were designed specifically to remove pesticides. The results of comparing treated with untreated water samples demonstrate that pesticide removal is not occurring with conventional water treatment.

C. Comparison of the Findings with Required Pesticide Monitoring

It is not surprising that of the six pesticide compounds required to be monitored at surface water supplies, only 2,4-D was detected. 2,4-D is, to date, one of the most commonly used agricultural pesticides in Iowa (refer to Table 5). Endrin, lindane, methoxychlor, Silvex and

TABLE 11

Analytical Results Comparing Treated (F-finished) and Untreated (R-raw) Water Samples
(µg/l or ppb)

Water Supply Name		atrazine	cyanazine (Bladex)	metolachlor (Dual)	alachlor (Lasso)	metribuzin (Sencor)	carbofuran (Furadan)	2,4-D	dicamba (Banvel)
Albia	R	1.1	1.4		0.21		1.8		
	F	0.97	1.2		0.24			N.A.	N.A.
*Bedford	R	0.47	0.12						
	F	0.59	0.13						
Clarinda	R	0.97	0.31	0.46					
	F	0.72	0.55	0.26					
Council Bluffs	R								
	F								
Davenport	R	0.24		0.1	0.23				
	F	0.18							
*Des Moines	R	0.47	0.44	1.2	0.98		0.72		
	F	0.34	0.29	0.69	0.59		0.38		
*Fort Madison	R	21.0	14.0	5.5	5.1	0.89	14.0	N.A.	N.A.
	F	6.0	4.6	1.7	1.7	0.28	4.7		
Humeston	R	26.0	20.0	10.0	0.13		17.0	.17	1.2
	F	24.0	17.0	8.3	0.16		14.0		1.4
Lakeview Heights	R	0.18							
	F	0.2							
Orient	R	1.9		1.0					
	F	0.60		0.3					
Ottumwa	R	0.88	0.57	0.72	0.28				
	F	0.71	0.46	0.51	0.29				
Panora	R	0.56	0.42	0.69	0.43				
	F	0.46	0.35	0.46	0.41				
Rathbun RWA	R	2.2	0.50	0.68	0.14				
	F	1.8	0.62	0.37					
University of Iowa	R	12.0	3.2	9.8	9.3		2.0	.15	
May 18, 1986	F	15.0	7.2	10.0	8.8	0.31	1.2	.15	
May 19, 1986	F	12.0	5.4	7.8	7.8	<0.1	6.0	N.A.	

N.A. = Not Analyzed
R = Raw (Untreated) Water
F = Finished (Treated) Water

*These facilities have more than one permanent untreated water source and finished water may be a blend.

toxaphene, the other pesticides required to be monitored, have limited use in Iowa. Silvex was removed from the market in 1983 and endrin, toxaphene and lindane (for commercial use) are restricted use pesticides.

While 2,4-D was detected in two of 33 (7%) of the treated water supply samples, atrazine (91%), cyanazine (79%), metolachlor (64%), alachlor (52%), carbofuran (27%) and metribuzin (12%) were detected more frequently and monitoring for these compounds is not required through the federal Safe Drinking Water Act (SDWA) regulations. The SDWA monitoring requirements appear to be inappropriate and inadequate in that no requirements have been imposed on the commonly used pesticides being detected in surface water supplies of the state, but instead include pesticides with EPA "restricted uses" or those of limited usage in the state.

D. Health Impacts

The pesticide concentrations observed in this study are below acute toxicity levels and in many cases below levels assumed to contribute to long-term, chronic problems such as cancer and immunosuppression. However, concerns for chronic health effects are legitimate considering the concentrations observed in this and other studies, the concern with long-term and widespread exposure, and the general lack of knowledge with regard to what constitutes a safe level of exposure over long periods of time.

Although MCLs have been established for 2,4-D and Silvex, work conducted in Sweden has found the formation of human soft tissue sarcomas to be linked to each of these pesticide compounds (Hardell and Sandstrom, 1979). Recent work at the University of Iowa has indicated that the post World War II population of Iowa farmers have a higher incidence of certain cancers than other farm populations or the state as a whole (Burmeister et. al., 1983). This coincides with major changes in agricultural practices, among which was the development of agriculture's heavy use of and reliance upon pesticides. This work is supported by related studies in Nebraska and Illinois which offer similar findings (Blair and Thomas, 1979; Buesching, 1986). A study conducted in Wisconsin has linked exposure to the pesticide aldicarb with changes in the immune system of 23 women. They were exposed by drinking contaminated well water with concentrations of the pesticide below 5 µg/l (Fiore, 1986).

Beyond concerns over chronic health effects which may result from direct ingestion of individual compounds, there are many uncertainties involved with the combination of pesticides and their metabolites that occur in relation to other environmental factors. For example, pesticides in surface water will usually appear in conjunction with other pollutants such as nitrate, and may be accompanied by inorganics (arsenic, heavy metals, etc) and organic solvents (tetrachloroethylene, gasoline components, etc.). The implications to human health of the coexistence of these chemicals in drinking water is unknown.

EPA's preliminary lifetime pesticide health advisory levels, also referred to as the maximum contaminant level goal (MCLG), for the ten pesticides detected in Iowa's surface water supplies can be found in Table 12. Table 12 also includes information on the carcinogenicity of each compound. The lifetime health advisory levels, or MCLGs, reflect calculated concentrations based upon non-carcinogenic, chronic (long-term) toxicity which appear to be without appreciable risk of deleterious effects over a lifetime of exposure. For a known or probable human carcinogen the lifetime health advisory level is zero. Information on carcinogenicity is calculated separately, and is presented in terms of various levels of risk rather than as a presumed safe threshold. The usual level of acceptable cancer risk is 10^{-6}, or

TABLE 12

Preliminary Health Advisory Levels

Pesticide	Lifetime Health Advisory Concentration Based on Chronic Toxicity *(ppb)	EPA Cancer Rating
atrazine	2.5	pending
alachlor (Lasso)	0	probable human carcinogen 10^{-6} cancer risk levels 0.6 ppb - adult 0.16 ppb - child
butylate (Sutan)	490	not classified (insufficient data)
carbofuran (Furadan)	35	not a carcinogen (no cancer appeared in animal studies)
cyanazine (Bladex)	9	not classified (insufficient studies available)
dicamba (Banvel)	1	not classified (insufficient data)
metribuzin (Sencor)	175	not classified (insufficient data)
metolachlor (Dual)	10.5	possible human carcinogen (some animal evidence)
trifluralin (Treflan)	2.1	possible human carcinogen (some animal evidence)
2,4-D	70	not classified (insufficient data)

*Assumes an average weight of a human as 70 kg, the average daily intake of water for that human was two liters and that 20% of the total intake is taken directly as drinking water.

one chance in a million. For alachlor (Lasso), the concentrations associated with a 10^{-6} cancer risk are 0.6 ppb for an adult and 0.16 ppb for a child. In comparing the levels in Table 12 to the analytical results of the treated water samples, 21 of 33 systems exceeded one or more of the preliminary lifetime health advisory concentrations or MCLGs, alone, and 17 of the 33 systems tested exceeded the accepted cancer risk level for children (the most susceptible population) of 10^{-6} with alachlor and seven of the 33 systems exceeded the accepted cancer risk level (0.6 ppb) for adults.

Because we are just beginning to identify pesticides in Iowa's drinking water and chronic disorders may require 20 years or more to manifest themselves, the impact to human health (and resulting economic cost associated with those illnesses) from exposure to low concentrations of one or more pesticides remains to be seen. Clearly, our understanding of the relationship between these chemicals and human health is severely limited. Appendix III provides a brief summary of available toxicity information for pesticides detected in this study.

E. Factors Affecting the Study Results

Additional information provided by water supply personnel collecting the sample(s) including the estimated amount of rainfall received, rainfall date(s) and date of sample collection can be found in Appendix II. In reviewing Appendix II which contains the information describing the circumstances of when the samples were collected, many variables are evident. Among the most obvious variables from Appendix II are: amount of rainfall received prior to sampling; sample collection date; and time between rainfall occurrence and sample collection. Other important variables, not readily obvious from the data in Appendix II, are: the time of pesticide application in relation to sample collection date; watershed size; and amount of runoff experienced.

Pesticides are applied at different times of the crop season. Some are applied as early pre-plant, some as pre-emerge and some as post-emerge. Generally, the first dose of pesticides are applied just prior to planting. It is difficult however to determine whether the pesticides detected in this study were from a recent or previous application.

A summary of statewide planting statistics for May and June 1986 is provided in Table 13. Planting completion and fertilizer application were influenced by weather conditions and thus did have regional differences which are not reflected in the statewide figures. Twenty-seven water supplies submitted samples in the month of May while seven supplies submitted samples that were collected between June 1st and July 11th. Rainfall amounts, after which samples were collected, ranged from 0.12 inch to over seven inches. Samples from some water supplies were collected shortly after the occurrence of rainfall while others were collected up to 11 days after rainfall. The different times of sampling after rainfall were probably related to the following factors: the size of the land area draining into the water body, the amount and intensity of the rainfall, time between rainfall and influence upon water quality, and, the sample collector's judgement of when the surface water was at its poorest quality.

TABLE 13

Statewide Planting Statistics*

Date	% of the Intended Corn Acres Planted	% of the Intended Soybean Acres Planted	Fertilizer Application Completed
April 28, 1986	5	0	64
May 5, 1986	20	0	70
May 12, 1986	65	8	88
May 19, 1986	75	15	90
May 27, 1986	88	35	93
June 2, 1986	92	55	96
June 9, 1986	98	82	
June 16, 1986		95	
June 23, 1986			

*Obtained from Iowa Crops and Weather weekly bulletins, published by Iowa Agricultural Statistics.

In regards to the sample collector's judgement for the timing of the collection of the water samples, several different methods were used. Most often indicated were: increased turbidity levels, increased water levels and increased nitrate levels. Increased nitrate levels may, however, have been related to increases in subsurface and tile drainage and, if used as an indicator for worst case conditions, may not necessarily have been representative of poorest case water quality resulting from surface runoff with regards to pesticide concentrations. Other studies suggest that in surface water as nitrate concentrations increase, pesticides would be decreasing.

Because of the number of variables affecting the results from the different sampled water supply systems, no comparison between the facilities can be made. The factors contributing to the lack of comparability also hold for determining the type of water source most susceptible to pesticide contamination. Thus, it cannot be determined among rivers, reservoirs or lakes which is most likely to be affected by pesticide contamination. The data, however, does clearly indicate that most surface water sources for public water supplies are susceptible to contamination with pesticides.

F. Comparison of Results with Previous Monitoring

The results from this study support the following findings from previous studies.

1. Surface water treatment systems are specifically designed to remove particulate matter including sediments to reduce turbidity levels in source water to acceptable drinking water standards. In 91% of the treated water samples analyzed in this study, one or more pesticides were detected. In those supplies collecting samples of both treated and untreated water, no significant reductions in

pesticide levels was provided for during the treatment process. These findings support other studies that indicate many of the now common pesticides are transported in solution rather than by sediments.

2. The results from this study contained above also support the previous ISU study findings that current treatment processes are ineffective at removing or eliminating pesticides from the water.

3. The pesticide compounds detected in this study are the predominant ones being found in other surface and ground water studies. Of the ten individual pesticides detected in both treated and untreated water samples, all are commonly used in Iowa (Table 5). Since the mid-1970's there has been an increase in the frequency of these compounds being detected in surface waters (Figure 2).

   because surface waters are directly influenced by rainfall events and subsequently runoff, surface waters would be expected to often contain compounds less likely to be detected in shallow ground water. Butylate and carbofuran were detected in this study of surface waters. These compounds have not been detected in ground water. Infiltration to the ground water is a slower process than direct transport to a stream; thus, pesticide concentrations in surface waters are likely to be higher than those characteristically found in ground water. The infiltration process may allow time for pesticide compound decay or breakdown. The pesticide concentrations detected in this study were generally higher than those routinely encountered in ground water.

IV. Conclusions and Recommendations

The following conclusions are based on the findings from this study.

1. Most surface waters used as a source for a public water supply are likely to contain one or more pesticide compounds, at the least, during periods of runoff in spring to early summer.

2. Conventional water supply treatment methods are ineffective at removing pesticides.

3. At least 22% of the state's population, using surface water sources for community public water supplies, are now consuming on a periodic basis one or more pesticide compound in their drinking water.

4. Pesticide monitoring required by the Safe Drinking Water Act regulations appears inadequate for Iowa. Except for 2,4-D, the six SDWA pesticides have limited usage within the State of Iowa. One of them, Silvex, is no longer marketed.

5. All of the ten individual pesticides detected as part of this study are commonly used in Iowa.

6. Except for 2,4-D, there are no monitoring requirements for the pesticides being found in Iowa's community public water supplies.

7. Most pesticides being found in community water supplies have no enforceable established standards or criteria to protect public health.

8. The current level of chemical management and agricultural practices are generally not effective at preventing pesticide contamination of surface waters.

9. Levels of some pesticides found at some treated water supplies currently exceed acceptable cancer risk levels or preliminary lifetime health advisory concentrations under the spring rainfall runoff conditions experienced during this study.

The following recommendations are proposed to better utilize resources for monitoring of public water supplies and to protect human health from pesticide contamination.

1. All commonly used pesticides should be monitored on a regular basis in public water supplies using surface water sources as a condition of their operation permit.

2. The state's public drinking water supply program should place more emphasis on public awareness of unregulated contaminants in the drinking water. A systematic approach for monitoring unregulated contaminants needs to be developed along with a means of informing the public of the occurrence of these unregulated contaminants.

3. The state should encourage and support changes to the Safe Drinking Water Act that more accurately reflect current pesticide usage. The establishment of MCLs and monitoring requirements need periodic review and updating to reflect changes in pesticide use and availability.

4. Since conventional water treatment is ineffective at eliminating pesticides from public water supplies and the implications to human health from exposure to these compounds is unclear, emphasis should be placed on prevention of surface water contamination through more efficient chemical usage and more environmentally sound agricultural practices.

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APPENDIX I

Analytical Results (µg/l or ppb)

(The entries below are reported values above the level of detection. If no entry is given, the pesticide was below the level of detection.)

Water Supply Name	Date Sampled in 1986	Type of Sample*	atrazine	cyanazine (Bladex)	metolachlor (Dual)	alachlor (Lasso)	metribuzin (Sencor)	trifluralin (Treflan)	butylate (Sutan)	carbofuran (Furadan)	2,4-D	dicamba (Banvel)
Afton	5-13	F	7.9	15.0	4.6	0.44						
Albia	5-19	R	1.1	1.4		0.21				1.8		
	5-19	F	0.97	1.2		0.24					NA*	NA
Bedford	5-12	R	0.47	0.12								
	5-12	F	0.59	0.13								
Bloomfield	5-07	R	1.3	1.3	0.80	0.27						
Burlington	5-05	F	0.49	0.20	0.33	0.34						
Central Water System	6-26	F	0.13									
Clarinda	5-27	R	0.97	0.31	0.46							
	5-27	F	0.72	0.55	0.26							
Clear Lake	5-14	F										
Corydon	6-03	F	21.0	0.61	21.0	0.25						
Council Bluffs	5-13	R										
	5-13	F										
Creston	5-20	F	0.75	0.45	0.24					0.18		
Davenport	5-12	R	0.24		0.1	0.23						
	5-12	F	0.18									
Des Moines	5-27	R	0.47	0.44	1.2	0.98				0.72		
	5-27	F	0.34	0.29	0.69	0.59				0.38		

APPENDIX I
- Continued -

Water Supply Name	Date Sampled in 1986	Type of Sample*	atrazine	cyanazine (Bladex)	metolachlor (Dual)	alachlor (Lasso)	metribuzin (Sencor)	trifluralin (Treflan)	butylate (Sutan)	carbofuran (Furadan)	2,4-D	dicamba (Banvel)
Fairfield	6-17	F	1.8	2.1		0.63	0.45					
Fort Madison	5-19	R	21.0	14.0	5.5	5.1	0.89			14.0	NA	NA
	5-19	F	6.0	4.6	1.7	1.7	0.28			4.7		
Greenfield	5-12	F	0.59	0.51				0.13				
Humeston	5-19	R	26.0	20.0	10.0	0.13				17.0	0.17	1.2
	5-20	F	24.0	17.0	8.3	0.16				14.0		1.4
Keokuk	5-19	F	1.7	0.91	0.61	0.76						
Lake Park	5-14	F	0.32	0.13	0.53	0.23						
Lake View Heights	6-30	R	0.18									
	7-02	F	0.2									
Lamoni	5-19	F	9.3	4.1	2.9					6.9	NA	NA
Lenox	5-28	F	0.46	3.1	0.1				0.27	1.78		
Montezuma	5-20	F	2.5	2.1	1.7	0.67	0.14			2.6		
Mount Ayr	7-11	F	3.6	1.3	2.2							
Mount Pleasant	5-27	F	5.8	3.9	2.8	2.4						
Orient	6-30	R	1.9		1.0							
	6-30	F	0.60		0.30							
Osceola	5-19	F	2.7	1.0		0.19				2.1	NA	NA
Ottumwa	7-02	R	0.88	0.57	0.72	0.28						
	7-03	F	0.71	0.46	0.51	0.29						

APPENDIX I
- Continued -

Water Supply Name	Date Sampled in 1986	Type of Sample*	atrazine	cyanazine (Bladex)	metolachlor (Dual)	alachlor (Lasso)	metribuzin (Sencor)	trifluralin (Treflan)	butylate (Sutan)	carbofuran (Furadan)	2,4-D	dicamba (Banvel)
Panora	5-12	R	0.56	0.42	0.69	0.43						
	5-12	F	0.46	0.35	0.46	0.41						
Rathbun RWA	5-22	R	2.2	0.50	0.68	0.14						
	5-22	F	1.8	0.62	0.37							
Spirit Lake	5-07	F										
Sun Valley	5-13	F	1.2	0.23								
University of	5-18	R	12.0	3.2	9.8	9.3				2.0	0.15	
Iowa	5-18	F	15.0	7.2	10.0	8.8	0.31			1.2	0.15	
Hintersat	5-15	F	3.2	2.5	0.41	1.0					0.30	

Abbreviations

NA = acid herbicides were not analyzed
R = raw (untreated) water
F = finished (treated) water

APPENDIX II

Sample Collection Information Provided by Sample Collectors

Name of Supply	Date of Rainfall 1986	Estimated Amount of Rainfall (inches)	Hydraulic Retention Time (hours)	Date and Time of Untreated Water Sample Collection*	Date and Time of Treated Water Sample Collection*
Afton	5-14	1.0	5.5		5-13 at 3:00 pm
Albia	not given	not given	not given	5-19 at 12:30 pm	5-19 at 12:30 pm
Bedford	5-09 to 5-11	2.75	6	5-12 at 10:45 am	5-12 at 10:45 am
Bloomfield	5-07	1.25	4	5-07 at 2:00 pm	
Burlington	4-29	> 2	24 to 30		5-05 at 1:00 pm
Central Water System	6-20 to 6-21	1.85	1.8		6-26 at 9:40 am
Clarinda	5-17	.5	1	5-27 at 7:30 am	5-27 at 6:35 am
Clear Lake	5-09 to 5-13	4.75	2		5-14 at 1:15 pm
Corydon	5-19 to 6-03	5	3		6-03 at 11:00 am
Council Bluffs	5-12	1	12	5-14 at 12:30 am	5-13 at 12:30 pm
Creston	5-15 to 5-17	3	4		5-20 at 9:09 am
Davenport	5-05 to 5-11	.12	3.5 to 4	5-12 at 12:40 pm	5-12 at 3:40 pm
Des Moines	not given	not given	not given	5-27 at 6:30 am	5-27 at 8:00 am
Fairfield	6-14	.5	6		6-17 at 2:00 pm
Fort Madison	5-16 to 5-17	3	3	5-19 at 10:00 am	5-19 at 1:00 pm
Greenfield	5-10 to 5-11	2.5	.33		5-12 at 11:30 am
Humeston	5-15 to 5-17	7 to 8	16	5-19 at 4:40 pm	5-20 at 8:20 am
Keokuk	5-16 to 5-17	3.5	8		5-19 at 1:00 am
Lake Park	5-12	2.06	1.5		5-14 at 10:00 am
Lakeview Heights	6-28 to 6-30	> 3	11 to 12	6-30 at 2:45 pm	7-02 at 12:00 pm
Lamoni	5-16	3.02	3		5-19 at 1:40 pm
Lenox	5-16 to 5-17	2	8		5-28 at 1:00 pm
Montezuma	5-13 to 5-19	3.99	6		5-20 at 2:00 pm
Mount Ayr	7-08 to 7-09	4	2.25		7-11 at 11:30 am
Mount Pleasant	5-16 to 5-17	4.4	14.5		5-27 at 9:00 am
Orient	6-29	1	1	6-30 at 2:00 pm	6-30 at 2:00 pm
Osceola	5-12 to 5-17	5	2		5-19 at 8:00 am
Ottumwa	6-30 to 7-01	1 to 1.5	16	7-02 at 4:30 pm	7-03 at 8:30 am
Panora	5-10 to 5-11	4	2.5	5-12 at 6:00 am	5-12 at 9:00 am
Rathbun RWA	5-15 to 5-17	5.25	4	5-22 at 4:00 am	5-22 at 8:00 am
Spirit Lake	4-27	.25	3		5-07 at 12:00 pm
Sun Valley	5-08 to 5-13	1.5 to 1.75	6 to 10		5-13 at 6:00 pm
University of Iowa	5-11 to 5-17	> 7	7.4	5-18 at 2:30 pm	5-18 at 10:00 pm
Winterset	5-14 to 5-15	2	6.7		5-15 at 3:30 pm

* 1986

APPENDIX III

Toxicity Information

The following is a data summary of toxicity studies for some commonly used pesticides. The values from these studies are used to determine acceptable daily intake and preliminary health advisory levels. In establishing these levels, standard safety factors are used. Typically used minimal safety factors are listed below.

Standard Safety Factors for Toxicological Effects

Effect	Safety Factor*
cholinesterase inhibition based on two-year rodent or dog studies	100
cholinesterase inhibition based on human NOEL (no observed effects level)	10
general toxicity based on chronic studies	100
cholinesterase inhibition based on subchronic studies	200
teratogenic effects	at least 100
general toxicity based on subchronic studies	2,000

*These are minimal safety factors and actual margins of safety may be higher.

COMPOUND	DATA SUMMARY
Atrazine	- Rat teratology, NOEL = 100 mg/kg 1-year dog feeding, - Negative mutagenicity (1 study) CORE supplementary:* - The other pivotal data are not adequate (CORE supplementary) to regulate this chemical - 2-year dog feeding, NOEL = 150 ppm (LDT) - 2-generation rat reproduction, NOEL = 100 ppm (HDT) using the 80W formulation

*The CORE classification system was developed by the Office of Pesticide Programs in 1977 to assess the adequacy of toxicology studies.

LDT = Low Dose Test
HDT = High Dose Test
IBT = Industrial Bio-Test Laboratories

COMPOUND	DATA SUMMARY
Metolachlor (Dual)	- 6-month dog feeding, NOEL = 100 ppm 6-month dog feeding, - 2-year supplementary (IBT) onco. in rat: weak oncogen, i.e., liver tumors - 2-year chronic in rat (repeat study): weak oncogen - liver tumors, NOEL = 30 ppm (testicular atrophy) - 2-year oncogen in mouse negative at 3,000 ppm (Highest Dose Tested (HDT) Industrial Bio-Test, validated) - 3-generation rat reproduction - 300 ppm - Teratology rat NOEL = 360 mg/kg (HDT) - Teratology rabbit NOEL = 360 mg/kg - Mutagenicity: negative (2 tests) - Positive skin sensitizer - 2-year oncogen in mouse: negative at 3,000 ppm (HDT)
Cyanazine (Bladex)	- Teratology in Fisher rat: a potential weak teratogen (NOEL for study not yet determined: 10 mg/kg for micro-ophthalia/anophthalmia, and pending additional studies, the NOEL may be lower than 1 mg/kg (LDT) for liver-induced hernia) - Teratology in SD rat: negative at 30 mg/kg (HDT) (however, MTD not tested) - Teratology in rabbit: negative at 4 mg/kg (HDT), NOEL = 1 mg/kg/day - 2-year oncogen in mice: negative at 1,000 ppm (HDT)
Metribuzin (Sencor)	- Rabbit teratology; NOEL = 15 mg/kg (HDT) - Mutagenicity: negative (3 tests). All the other pivotal data were not CORE classified - 2-year dog feeding; NOEL = 100 ppm - 2-year rat feeding/oncogen, negative for oncogencity; NOEL = 300 ppm - 2-year mouse oncogen, negative at 3,200 ppm (HDT) - Rat teratology, NOEL = 100 mg/kg (HDT) - 3-generation reproduction, NOEL = 300 ppm
Trifluralin	- Rabbit teratology; NOEL = 450 mg/kg (supplementary data) not CORE classified - 4-generation rat reproduction; NOEL = 200 ppm (LDT) (supplementary data). All other pivotal data were not CORE classified. - Mouse onco: positive, hepatocellular adenoma and carcinoma, alveolar-bronchiolar adenoma, and squamouscell carcinoma in female mice - Rat onco: negative at 6,500 ppm (HDT) - Reproduction: dog, NOEL = 25 mg/kg - 2-year feeding rat, NOEL = 2,000 ppm - 3-year dog, NOEL = 10 mg/kg (liver weight changes) - 2-year dog, NOEL = 10 mg/kg (HDT)